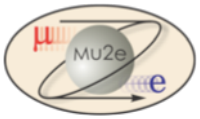
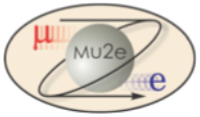





# Mu2e & the CMS-Lite Framework

Rob Kutschke, Fermilab February 11, 2010

http://mu2e-docdb.fnal.gov/cgi-bin/ShowDocument?docid=779




# CMS-Lite

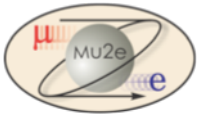
- Not an official name
  - CMS has something else called the same thing ( spelling?).
- Start with CMS's software.
  - Strip out things that we do not need or which CMS scientists find too hard to use.
- Runs on:
  - SLF 4 and 5
  - 32 and 64 bit hardware.
- No plans to port to Windows.
- Might port to Mac some day?

# Finding the Tutorials

- Home page:
  - http://mu2e.fnal.gov
  - Click on “Mu2e For Physicists” button at the top
  - The Mu2e Offline Software
  - Running G4 in the Mu2e Framework on ilcsim* and FNALU
- You all have accounts on ilcsim and ilcsim2.
  - ssh –Y ilcsim ( and forward kerberos creds).
- You all have permission to use the cvs repository.
  - Must have kerberos creds.
  - http://mu2e.fnal.gov/public/hep/computing/cvs.shtml
  - setenv CVSROOT mu2ecvs@cdcvs.fnal.gov:/cvs/mu2e
  - setenv CVS_RSH /usr/bin/ssh

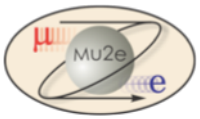
# setup.sh

- Must source from bash.
- $MU2E_HOME
  - Misnamed.  Should be $FRAMEWORK_HOME.
- $MU2E_EXTERNALS
  - Most of the external packages: root, boost, CLHEP
- $GEANT4_DIR
  - We find G4 using ups/upd.
- $LD_LIBRARY_PATH
  - ./lib plus framework, externals and G4.
- The code you check out is the full code Mu2e code base.
  - No concept of base release yet.



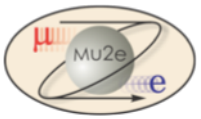

# 3 Part Event Id

- Run / LuminosityBlock / Event
  - Expect this to be good enough for us.
- Run:
  - 0 or more luminosity blocks.
- LuminosityBlock:
  - 0 or more events.
  - must be contained within one file.
- A file may contain multiple LuminosityBlocks, multiple runs.



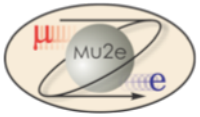

# Start the Tutorials

- Make sure you can run
  - g4test_01.py
  - g4test_02.py
  - g4test_03.py
  - readback.py
- Then we will look at the code, run time configuration files for readback.py and work backwards.




# Some Files from ReadBack Example

- mute
  - The executable
- Mu2eG4/test/readback.py
  - Run time configuration information for
    - Framework, all modules, all services
- Module Source
  - Mu2eG4/src/ReadBack.hh
  - Mu2eG4/src/ReadBack.cc
  - Mu2eG4/src/ReadBack_plugin.cc
- Mu2eG4/test/geom_01.txt
  - Geometry description.

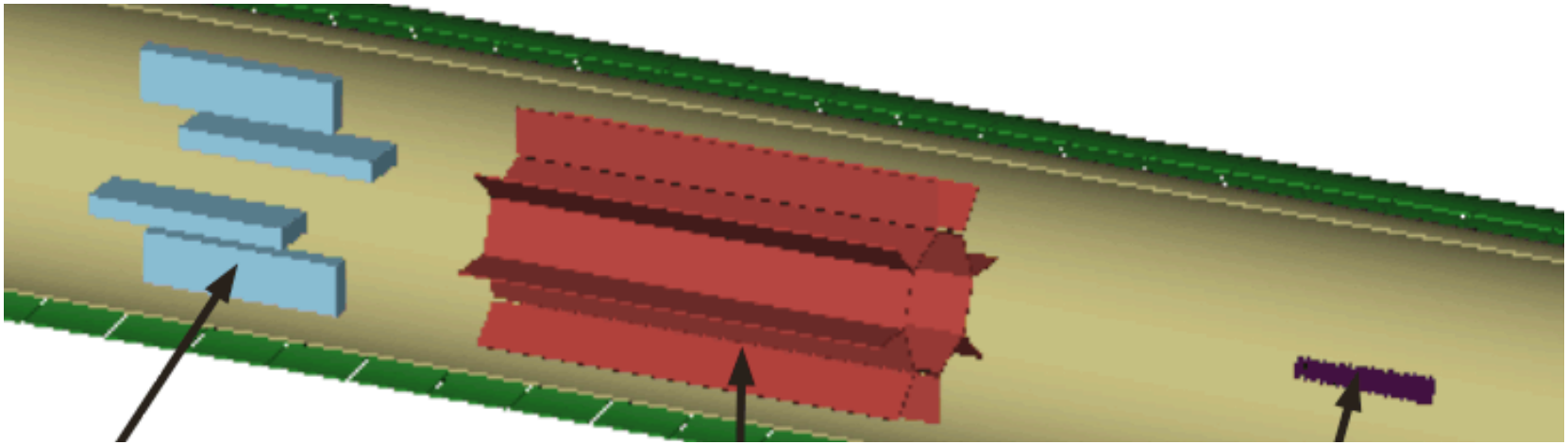


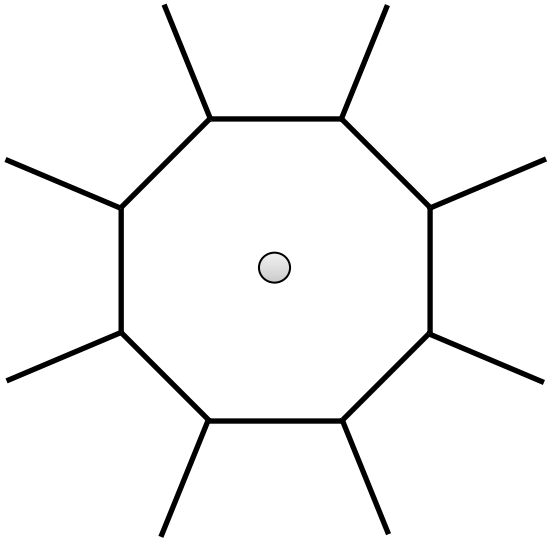

# What's in the Input File?

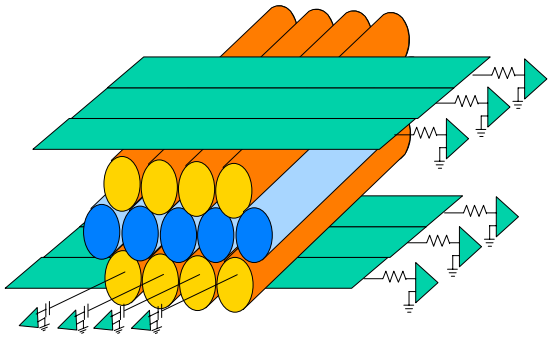
```
int                 _trackId;
VolumeId_type       _volumeId;
double              _enegyDeposition;
CLHEP::Hep3Vector   _position;
CLHEP::Hep3Vector   _momentum;
double              _time;
```

- ToyDP/inc/StepPointMC.hh
- Represents the intersection of a track in G4 with a volume in the detector.
  - In this example: the exit point from a straw in the Ltracker.
- typedef vector<StepPointMC> StepPointMCCollection;
- The input file contains one StepPointMCCollection.
- Name of the module that made it is: g4run.

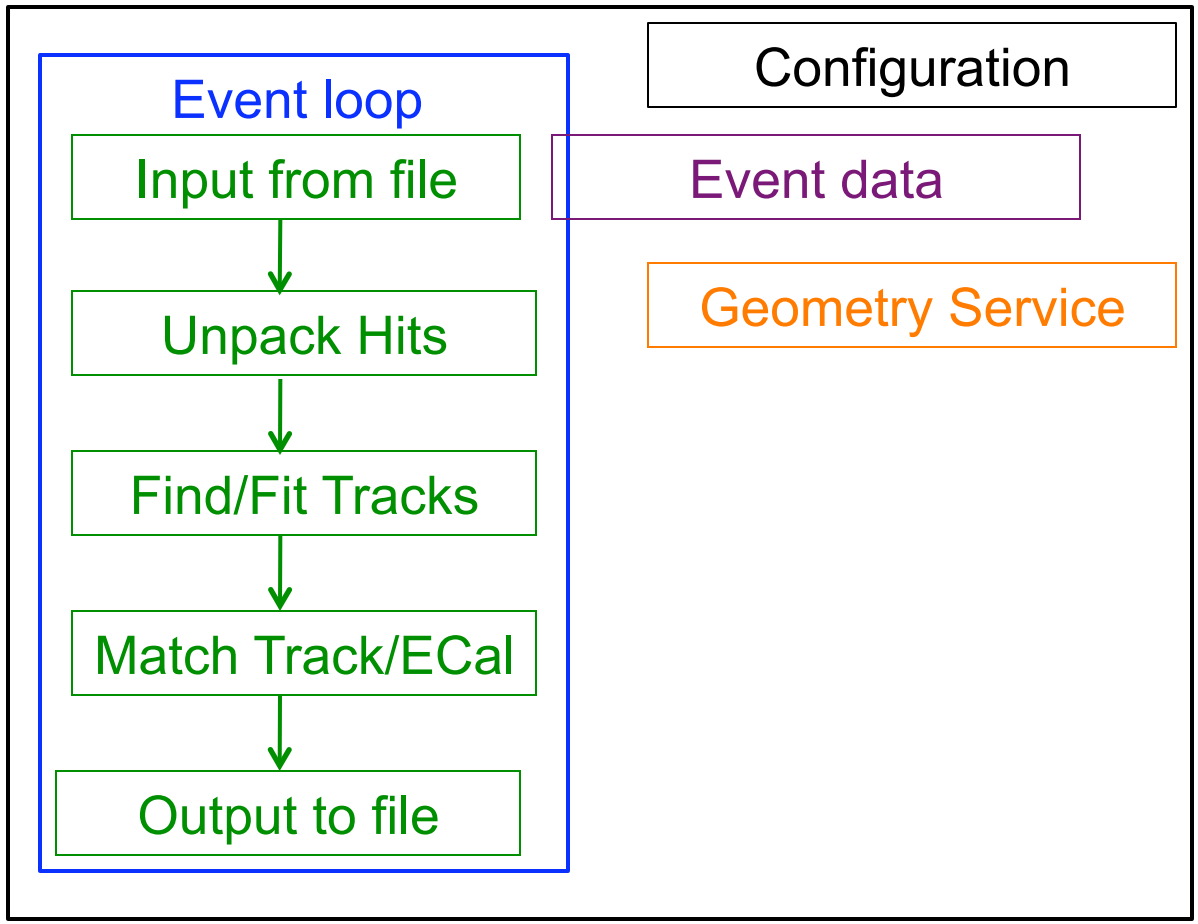
# The Mu2e LTracker



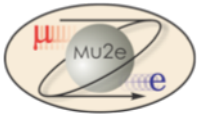




# Cartoon of Some Major Elements

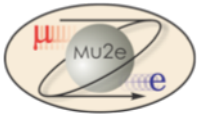



Framework Modules Services Files/DB Data in Memory




# Comments on Previous Slide

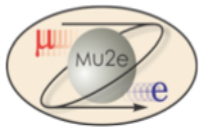
- Black: framework including configuration
- Blue: event loop
- Purple: data in memory that can be stored in files.
- Green: Modules
  - User code that can be called by the framework.
- Orange: Services
  - You will write code for the Geometry or Conditions services and maybe some others.
- Red: external files
  - Run time config configures: framework, each module, each service.
  - Geometry file: will some day live in a db.



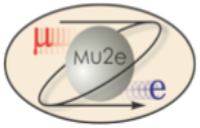

# Services

- Only one instance of each service class within a job
  - Geometry, Condidations data …
- Can be used inside all modules
- Instantiated, owned and managed by framework.
- Configuration from the run time configuration file.
- Framework calls services for:
  - beginJob, beginRun, beginLuminosityBlock

# Mu2eG4/src/ReadBack.hh

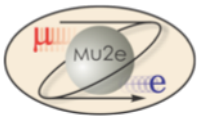



```
#include "FWCore/Framework/interface/EDAnalyzer.h"
#include "FWCore/Framework/interface/Event.h"
#include "FWCore/ParameterSet/interface/ParameterSet.h"

namespace mu2e {

  class ReadBack : public edm::EDAnalyzer {
  public:

    explicit ReadBack(edm::ParameterSet const& pset);
    virtual ~ReadBack() { }

    virtual void beginJob(edm::EventSetup const&);

    void analyze(const edm::Event& e, edm::EventSetup const&);

    // plus data members (next page) and other function members.

  };
}
```



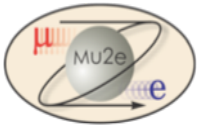

# ReadBack.hh continued

```
double _minimumEnergy;
int _maxFullPrint;
int _nAnalyzed;

// Pointers to histograms  and ntuples to be filled.
TH1F* _hRadius;
TH1F* _hEnergyDep;
TH1F* _hTime;
TH1F* _hMultiplicity;
TH1F* _hDriftDist;
TH1F* _hxHit;
TH1F* _hyHit;
TH1F* _hzHit;
TH1F* _hHitNeighbours;
TH1F* _hCheckPointRadius;
TNtuple* _ntup;
```




# Comments on Previous 2 Slides

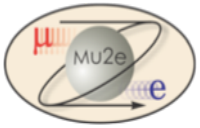
- Namespace: avoid collisions with 3rd party names.
- Must inherit from a module base class
  - EDAnalyzer: event is readonly
  - EDProducer: can add information to the event
  - EDFilter: can tag an event to go to a particular output file.
- Run time parameters passed to c'tor: edm::ParameterSet
- Event data passed into analyze is const edm::Event .
- Ignore edm::EventSetup
  - Leftover from CMS
  - Will go away.
- Lots of other allowed methods: see next slide.




# Other Methods of EDAnalyzer

$MU2E_HOME/FWCore/Framework/interface/EDAnalyzer.h

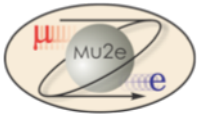
```
virtual void analyze(Event const&, EventSetup const&) = 0;
virtual void beginJob(EventSetup const&){}
virtual void endJob(){}
virtual void beginRun(Run const&, EventSetup const&){}
virtual void endRun(Run const&, EventSetup const&){}
virtual void beginLuminosityBlock(LuminosityBlock const&, EventSetup const&){}
virtual void endLuminosityBlock(LuminosityBlock const&, EventSetup const&){}
virtual void respondToOpenInputFile(FileBlock const& fb) {}
virtual void respondToCloseInputFile(FileBlock const& fb) {}
virtual void respondToOpenOutputFiles(FileBlock const& fb) {}
virtual void respondToCloseOutputFiles(FileBlock const& fb) {}
```




# Specifying Include Files

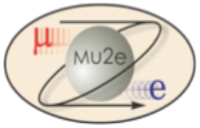
```
// Framework includes
#include "FWCore/Services/interface/TFileService.h”

// Mu2e includes
#include "GeometryService/inc/GeometryService.hh"

// Root includes.
#include "TH1F.h”

// G4 includes
#include “G4VPhysicalVolume.h”

// Other includes
#include "CLHEP/Units/SystemOfUnits.h"
```

- Mu2e code: relative to Offline
- Framework: relative to its root
- External: use style that is native to each package.




# More About Include files

- Some include files are in:
  - Package/inc/File.hh
  - Package/src/File.hh
- Why?
- If class is only for use inside the package, put it in src. Otherwise put it in inc.
- You can choose to do it differently.




# EDAnalyzer Module Constructor

```
ReadBack::ReadBack(edm::ParameterSet const& pset) :
  _minimumEnergy(pset.getParameter<double>("minimumEnergy")),
  _maxFullPrint(pset.getUntrackedParameter<int>("maxFullPrint",5)),
  _nAnalyzed(0),
  _hRadius(0),
  _hTime(0),
  // Plus the rest
  { }
```

- Parameter set comes from the .py file.
- Tracked vs untracked.  See next page.
- Reminder: initialize in order given in  .hh file.

# Run Time Configuration File

```
process.checkhits = mu2e.EDAnalyzer(
    "ReadBack",
    minimumEnergy = mu2e.double(0.001),
    maxFullPrint = mu2e.untracked.int32(3)
)
```

- Class name of module:
  - lib/libReadBack.so
  - SomePackage/src/ReadBack_plugin.cc
- Module Label: must be unique within one job.
- Parameter Set:
  - Remaining parameters to closing.
  - Tracked and Untracked: see next page.
  - A parameter can have a value that is another parameter set.

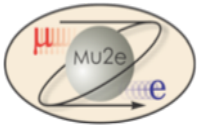
# Tracked vs UnTracked Parameters

- Tracked
  - Must be present in the configuration file or it is a run time error.
  - Values are included in the event data file.
  - Audit trail.
- Untracked
  - Coder can assign defaults to use if parameter is absent in the config file.
  - Not written to the event data file
- Up to us to use this feature wisely.

# beginJob

```
void ReadBack::beginJob(edm::EventSetup const& ){

  edm::Service<edm::TFileService> tfs;

  _hRadius      = tfs->make<TH1F>( "hRadius",
                                   "Radius of Hits;(mm)",     100,  0., 1000. );
  _ntup         = tfs->make<TNtuple>( "ntup", "Hit ntuple",
                                      "evt:trk:sid:hx:hy:hz:wx:wy:wz:dca:time:dev:sec");
}
```

- TFileService
  - new T(...) replaced by tfs->make<T>(…)
  - Manages conflicts with root IO.
  - Puts your histograms in a unique subdirectory.
    - May make your own subdir's under this.
- Or make per run histograms in beginRun.




# analyze

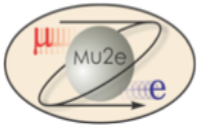
```
void ReadBack::analyze(const edm::Event& event, edm::EventSetup const&) {

  // Call code appropriate for the tracker that is installed in this job.
  edm::Service<GeometryService> geom;
  if( geom->hasElement<LTracker>() ){
    doLTracker(event);
  }
  else if ( geom->hasElement<ITracker>() ){
    doITracker(event);
  }

}
```

- Geometry service holds the geometry in a representation that is appropriate for reconstruction.
- Details later.
- LTracker and ITracker are competing designs; don't yet understand the true commonalities.

# Accesing Hits

```
void ReadBack::doLTracker(const edm::Event& event){

  // Ask the event to fill a handle to the requested hits.
  edm::Handle<StepPointMCCollection> hits;
  event.getByLabel("g4run",hits);

  // Fill histogram with number of hits per event.
  _hMultiplicity->Fill(hits->size());
```

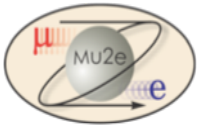
- typedef vector<StepPointMC> StepPointMCCollection;
- Handles:
  - Throws if the requested object could not be found.
  - Otherwise behaves like a pointer.
- getByLabel
  - Looks for a data product of the requested type that was created by a module with the label "g4run".




# Message Logger

```
// A silly example just to show that we have a messsage logger.
if ( hits->size() > 75 ){
  edm::LogWarning("HitInfo")
          << "Number of hits "
          << hits->size()
          << " is too large.";
}
```

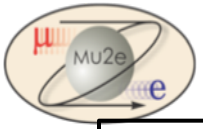
- Severities: Debug/Info/Warning/Error
  - With and without framing data: module, date, time.
- Suppress repeated printout
- End of job summary.
- Separate routing for different classes of messages.
- Much more configurable that we will ever need.




# Exceptions

```
// A silly example just to show how to throw.
if ( hits->size() > 1000000 ){
  throw cms::Exception("RANGE")
    << "Way too many hits in this event.  Something is really wrong."
    << hits->size();
}
```

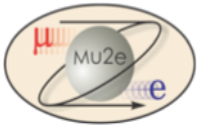
- Framework will catch exception and end job gracefully.
- Can configure framework to:
  - skip this module; skip to next event; skip to next run; etc.
  - Do it differently for different exceptions.




# Combining Hit and Geometry Info

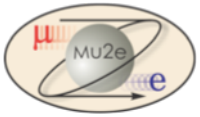
```
GeomHandle<LTracker> ltracker;        // Geometry for the Ltracker from Geometry Service.
 float nt[13];                        // ntuple buffer.

 // Loop over all hits.
 for ( size_t i=0; i<hits->size(); ++i ){

   // References (aliases) for readability.
   const StepPointMC& hit = (*hits)[i];

   // Skip hits with low pulse height.
   if ( hit.eDep() < _minimumEnergy ) continue;

   // Get the hit information.
   const Hep3Vector& pos   = hit.position();
   const Hep3Vector& mom = hit.momentum();

   // Get the straw information:
   const Straw&      straw    = ltracker->getStraw( hit.strawIndex() );
   const Hep3Vector& mid  = straw.getMidPoint();
   const Hep3Vector& w     = straw.getDirection();
```

- Heavy use of references: no copies.
- Use pointers only when necessary.



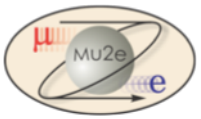

# The rest of doLTracker()

```
// Compute an estimate of the drift distance.
TwoLinePCA pca( mid, w, pos, mom);

// Fill some histograms
_hRadius->Fill(pos.perp());
_hEnergyDep->Fill(hit.eDep()/keV);
_hTime->Fill(hit.time());
_hHitNeighbours->Fill(nNeighbours);
_hCheckPointRadius->Fill(point.mag());

// Fill the ntuple.
nt[0]  = event.id().event();
nt[1]  = hit.trackId();                    // and so on

_ntup->Fill(nt);
```



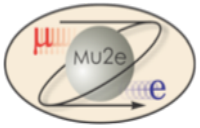

# Geometry Philosophy

- Three clients:
  - Reconstruction/Analysis  G4  Visualization
  - Very different requirements.
  - One must be authoritative and others derived.
- Have seen many bad experiences with 1 size fits all
  - Especially when reconstruction/analysis is considered last.
- My choice:
  - Classes in GeometryService are designed for reconstruction.
  - Write code to create G4 and visualization from this.
  - It should be easy to diff two geometry descriptions.
    - Geometry text files are compact, O(200) numbers to describe Mu2e.  The corresponding GDML file will be many MB




# Making Module or Service

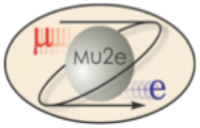
- Three separate files:
  - Module.hh, Module.cc, Module_plugin.cc
  - Examples:
    - Mu2eG4/src/ReadBack*
    - GeometryService/src/GeometryService*
- Or you can do it all in one file:
  - Mu2eG4/src/G4_plugin.cc




# ReadBack_plugin.cc

```
#include "Mu2eG4/src/ReadBack.hh"
#include "FWCore/Framework/interface/MakerMacros.h"

using mu2e::ReadBack;
DEFINE_FWK_MODULE(ReadBack);
```

- The macro puts code in lib/libReadBack_plugin.so
  - Factory method to new an object of the class.
  - Automagically register the factory with the framework.
- For some notes on how this works
  - http://mu2e.fnal.gov/public/hep/computing/dynamicLibraries/dynamic.shtml

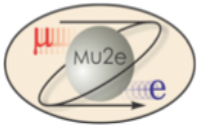



# Exercise 1

## ReadBack.cc

```
if ( hits->size() > 1000000 ){
    throw cms::Exception("RANGE")
      << "Way too many hits in this event.  Something is really wrong."
      << hits->size();
  }
```

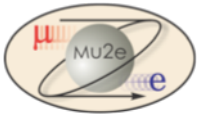
- Change 1000000 to 100; scons and re-run.
- Framework will catch exception and shutdown gracefully.
- Histograms are written out.
- Can configure framework to skip to next event, skip to next run, abort hard …




# Exercise 2: readback.py

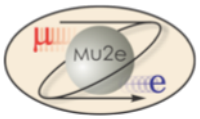
```
process.lowcut = mu2e.EDAnalyzer(
    "ReadBack",
    minimumEnergy = mu2e.double(0.001),
    maxFullPrint = mu2e.untracked.int32(3)
)

process.highcut = mu2e.EDAnalyzer(
    "ReadBack",
    minimumEnergy = mu2e.double(0.002),
    maxFullPrint = mu2e.untracked.int32(0)
)

process.output = mu2e.EndPath(  process.lowcut*process.highcut );
```

- Add a second instance of the module ReadBack
- Inspect the root file.  See two subdirectories.




# Package/src/SConscript

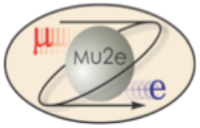
- *.cc  but not *_plugin.cc files.
  - Compile.
  - Add to lib/libPackage.so
  - You edit SConscript to add link time dependencies by hand.
- XXXXXX_plugin.cc
  - Compile each to form lib/libXXXXXX_plugin.so
  - May make many of these in one package
  - lib/libPackage.so is added as a link time dependency to all XXXXXX_plugin.so files.
- .os files are object files destined for .so libraries (distinguished from .o destined for .a )
- Inherits environment from Offline/SConstruct




# Mu2eG4/test/readback.py

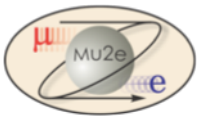
```
# Define the default configuration for the framework.
import FWCore.ParameterSet.python.Config as mu2e

# Give this job a name.
process = mu2e.Process("ReadBack01")

# Maximum number of events to do.
process.maxEvents = mu2e.untracked.PSet(
    input = mu2e.untracked.int32(200)
)

# Load the standard message logger configuration.
# Threshold=Info. Limit of 5 per category; then exponential backoff.
process.load("Config/MessageLogger_cfi")
```

- Mostly boilerplate. I find this language verbose



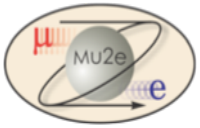

# Configure 3 of the Services

```
# Load the service that manages root files for histograms.
process.TFileService = mu2e.Service("TFileService",
                    fileName = mu2e.string("readback.root"),
                    closeFileFast = mu2e.untracked.bool(False)
)

# Initialize the random number sequences.
# This just changes the seed for the global CLHEP random engine.
process.RandomNumberService = mu2e.Service
("RandomNumberService",
                        globalSeed=mu2e.untracked.int32(9877),
)

# Define the geometry.
process.GeometryService = mu2e.Service("GeometryService",
      inputfile=mu2e.untracked.string("Mu2eG4/test/geom_01.txt")
)
```

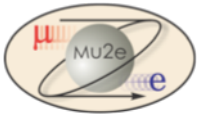



# RandomNumber Service

- Eventually this will be able to chain random number sequences across chains of jobs.
- Will be able to preserve the state of many independent generators.
- For now it just sets the seed in the global instance of the flat CLHEP engine.

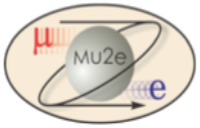



```
# Read events from a file (made by example 3)
process.source = mu2e.Source("PoolSource",
   fileNames = mu2e.untracked.vstring("data_03.root")
)

# Look at the hits from G4.
#  - minimum energy is in MeV
process.checkhits = mu2e.EDAnalyzer( "ReadBack",
    minimumEnergy = mu2e.double(0.001),
    maxFullPrint = mu2e.untracked.int32(3)
)

# End of the section that defines and configures modules.

# Tell the system to execute the modules in this order.
process.output = mu2e.EndPath(  process.checkhits );
```



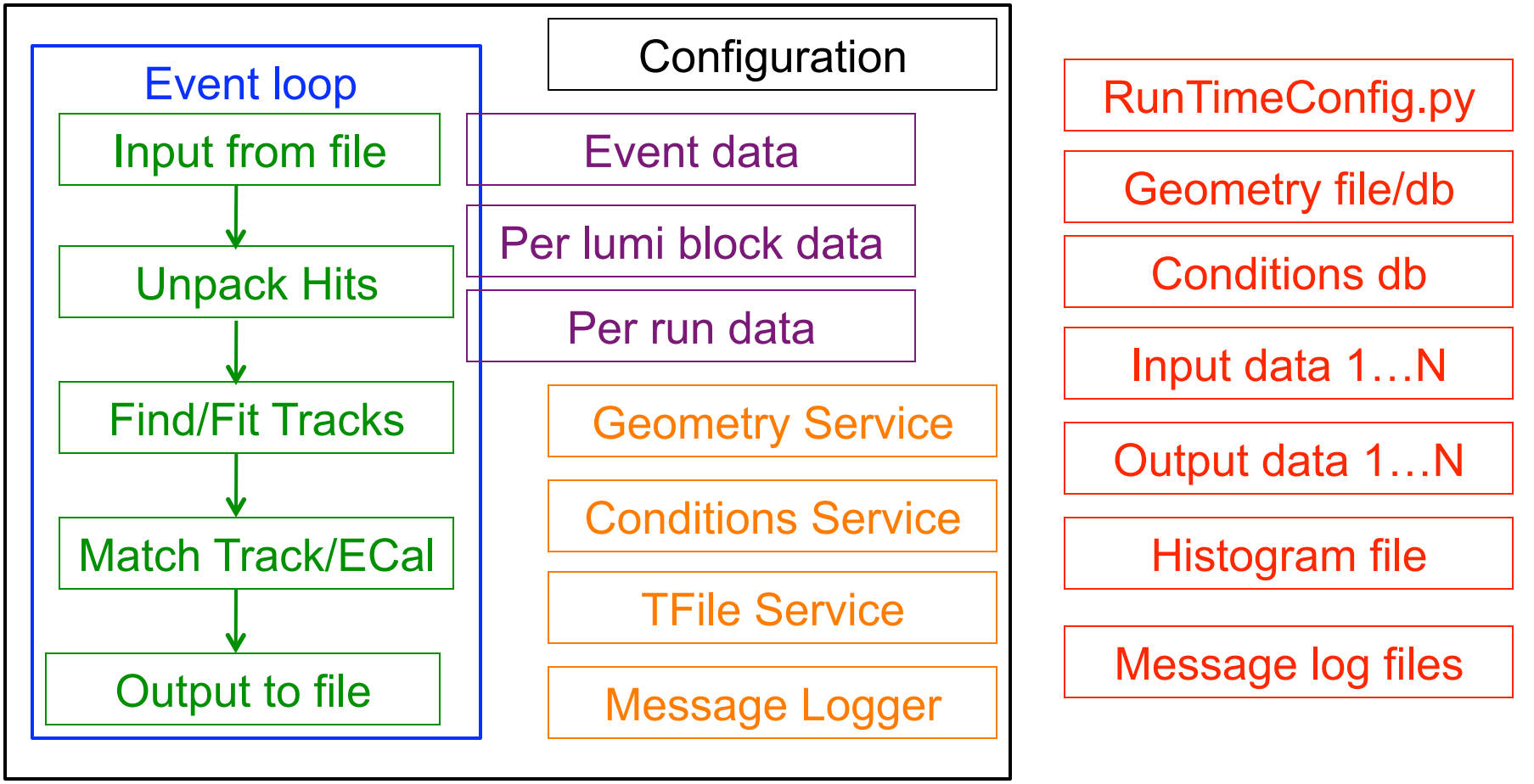

# Adding Data to the Event

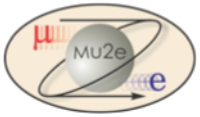
- Write an EDproducer module
- Need to tell the system about the classes that may be persisted.
- Described in:
  - http://mu2e.fnal.gov/public/hep/computing/DataProducts.shtml
- Example in:
  - HitMakers/src/MakeCrudeStrawHit_plugin.cc
  - HitMakers/test/makehits.py




# Backup Slides

# Cartoon of the Major Elements






# Comments on Previous Slide

- Black: framework including run time configuration
- Blue: event loop
- Purple: data that can be stored in files.
- Green: Modules
  - This is where most of your code will go.
- Orange: Services
  - Some of you might write code for the Geometry service.
- Red: external files
  - Geometry file: will some day live in a db.
- Message logger:
  - Direct messages to different files based on severity and category.